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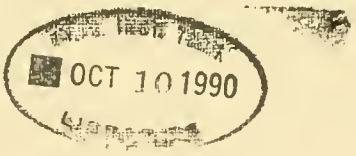

WORKING PAPER

Managing the Introduction of New Process Technology: International Differences in a Multi-Plant Network

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August 1990 WP # 12-90

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ABSTRACT

This paper examines the introduction of new technologies in the manufacturing environment and addresses two central questions. First, how can factories introducing new process technology deal with change rapidly and effectively? Further, what fundamental organizational changes are necessary to enable plants to respond successfully to the challenge of technological change?

The research examined 48 projects where new manufacturing technologies were introduced. Projects were undertaken in plants in Italy, West Germany, and the United States which belong to a single company. In comparing success across regions, performance measured by startup time and operating improvement was significantly lower in the U.S. plants than in European operations. A significant portion of this performance gap can be explained by differences in the way project teams in each region used available mechanisms for identifying and solving the problems associated with new technologies. U.S. project teams were, on average, less likely than those in Europe to engage in preparatory problem-solving activities, or to solve problems by working with external technical experts, or by merging different functional perspectives within the project group.

To understand the source of these differences, the paper examines historical and organizational differences among the operations in different geographic regions. Over time, local managerial choices had resulted in distinct sets of organizational capabilities, resources, and assumptions that affected the way plants in different regions approached technological problem solving. This paper argues that such managerial choices constitute important strategic decisions which have long-lived implications for technological innovation in the manufacturing environment.

INTRODUCTION: THE CHALLENGE OF TECHNOLOGICAL CHANGE

There is mounting evidence that, despite rapid advances in the technology of manufacturing equipment and systems, U.S. firms are failing to implement and exploit these technologies effectively. Jaikumar [21], for instance, argues that U. S. managers "are buying the hardware of flexible automation --but they are using it very poorly. Rather than narrowing the competitive trade gap with Japan, the technology of automation is widening it further" (p. 69). Thurow [39] blames "America's poor productivity, quality, and trade performance" squarely on inferior capabilities in introducing and using process technology (p. 1660). According to the Manufacturing Studies Board, U.S. companies need to "reemphasize process improvements -- selecting, using, and implementing available manufacturing technologies" [18,29].

Too often, when companies introduce new manufacturing processes they not only fail to capture competitive benefits but also experience a persistent drain on human and capital resources. One major U.S. study found that the difficulties of introducing new manufacturing equipment frequently result in productivity losses equal to or exceeding the original cost of the equipment, and that the disruptive effects can persist for two years or more [9,18]. Persistent problems can have serious competitive implications as deliveries, reputation, and market share slip. Further process change becomes impossible, while competitors' process technologies steadily move ahead.

Despite evidence of serious problems, little work has addressed the problem of utilizing new technology. Much of the existing reearch on process innovation and diffusion has focused on the decision to adopt new technology, rather than on the process of learning to use a new technology once it has been brought into the organization [23,35]. Further, existing research on "implementation" issues focuses primarily on developing organizational attitudes and receptivity to change[1]. This is a useful first step, but it fails to illuminate

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[1] This research tradition is represented by two streams of research. First, much of the early "implementation" research examined the different requirements of various stages in the innovation process. Many authors concluded that implementation, as distinct from development, calls for relatively tight forms of managerial control [37,44]. Another research stream focuses on creating user receptivity to the new technology [e.g. 28,30].

the behaviors needed to identify and address the problems involved in technological process change.

Process Change as a Form of Technological Innovation at the Plant Level

The premise of the paper is that the success of a new process introduction project is not just a function of user receptivity. Successful technological change also requires active organizational efforts to adapt the new technology, the existing manufacturing system, and the organization itself to a new set of demands [1,25,42]. Consequently, new process introductions often involve considerable problem solving and even innovation at the plant level [22,34]. However the plant's ability to identify problems and to develop new solutions is likely to be influenced by "embedded" characteristics of the organization, such as the sophistication of its manufacturing infrastructure, its existing base of technical competencies, and its repertoire of familiar problem solving methodologies [15,36]. Indeed, as Adler [2] points out, to understand organizations' success with new manufacturing technologies one must not only understand the behavior patterns in a specific project, but also analyze the underlying "web of more enduring organizational features that shape both the technology development effort and the project manager's margin of manoeuvre" (p. 194).

This research was undertaken to explore the determinants of successful plant-level problem solving and adaptation around new process technology. The study identifies organizational mechanisms for adapting both the new technology and the existing organization, and tests their impact on project success. Further, the paper attempts to place project-level performance in the context of the larger organizational setting. Regional variations in project strategies and project performance in a multi-plant, multi-national network are identified, and factors that could account for such variation are proposed. In particular, the analysis focuses on differences in the nature of the technical capabilities, operating practices, and working relationships developed at the regional level. Results suggest that these organizational factors have an enduring and important influence on factories' ability to adapt in the face of technological process change. Indeed, findings indicate that the managerial choices which shape such organizational characteristics should be seen as long-

term strategic decisions, capable of influencing operating performance and technological options well into the future.

This paper is organized in five parts. Part I draws on existing literature to identify three principal organizational response mechanisms for dealing with technological change. Part II describes the research methodology and the variables used in the analysis. Part III examines the data on project attributes and project success, and compares results across regions. Part IV discusses some of the forces which may explain the differential success of introduction projects in various regions. Part V presents conclusions and suggestions for further research.

I. ORGANIZATIONAL RESPONSES TO TECHNOLOGICAL CHANGE

Innovation theory suggests that organizations adapt to the uncertainties and problems associated with new technologies in a variety of ways. Two distinctions are used to categorize adaptive response mechanisms. First is the temporal distinction between problem solving in preparation for the introduction, and real-time adaptation during actual implementation of the technology [13,15,35]. The timing of problem solving relative to physical installation of the equipment affects the nature of the information available, the ease of making changes, and the impact of these changes on other parts of the factory [7,9]. The second basic distinction concerns the mechanisms for real-time problem solving or adaptation during implementation. Theory suggests that both interorganizational and intraorganizational collaboration are important for coping with new technology, but that they involve different integration processes and pose different kinds of problems [5,25,32].

Based on these distinctions, this study examines three mechanisms for adaptation and problem solving in response to process change. The first mechanism, preparatory search, refers to adaptation undertaken before introduction of the new technology into the plant setting. The second and third mechanisms refer to adaptation activities undertaken once the new technology is in place, but distinguish cross-functional, intraorganizational efforts from interorganizational activities. These mechanisms are not mutually exclusive, but are sufficiently different to warrant separation conceptually and

empirically.

1. Preparatory Search involves the investigation, modification, or "reinvention" of the new technology and relevant aspects of the receiving organization before the technology is installed in the factory [34,35,42]. This may involve adapting existing manufacturing systems, routines and procedures [8,9]. Coordination with internal or external developers of process equipment is an important aspect of preparatory search, allowing the mutual adaptation of the technology and the receiving environment during the early phase of the project [25].

The second and third response categories both involve real-time mechanisms for adapting to problems and opportunities which develop as the organization gains experience with the new technology.

2. Joint Search involves coordination with knowledgeable individuals from facilities or organizations external to the manufacturing plant. The notion of joint organizational search stems from the concept of an "organization set" [12,38] or, more specifically, a unit's "technological organization set" [27]. The latter can be defined as a coalition of suppliers of technology, equipment, components, or information. Research suggests that joint problem solving among members of the relevant technological organization set can account for "a major part of the company's problem solving capability with respect to the new technology" [27, p. 8; see also 11,19].

3. Functional Overlap involves linking relevant functions within the organization to create "overlapping" subsystems or multifunctional teams for dealing with change [13,14,24]. In the manufacturing environment, key functions include the plant technical or engineering activities and direct management of production output. Tighter linkage between these areas moves the locus of decision-making closer to the source of relevant information, and therefore increases the organization's ability to respond to uncertainty [6,31].

One of the principal objectives of the research was to examine the role of the above response mechanisms in technological process change. Several propositions guided the investigation. First, it was anticipated that greater use

of these response mechanisms at the plant level would be associated with more successful introductions of new process technology. Second, it was expected that operations in different geographical regions would display distinct patterns in their use of the response mechanisms identified. Finally, at the qualitative level, it was expected that significant differences among regional operations in the use of preparatory search, joint search, and functional overlap would be linked to different managerial policies across regions.

II. RESEARCH METHODOLOGY

Methodology and Data Gathering

The introduction of new technology into existing plants is a complex process. Progress may be affected by multiple, often subtle factors related to the project and its context. Understanding these factors typically requires in-depth clinical analysis of individual cases. However, in order to identify systematic patterns among projects, this complexity must be compressed into a few standardized measures. To meet these competing demands, the author collected three kinds of data: descriptive information about projects, their history and contexts through open-ended and semi-structured interviews; specific data on project characteristics and outcomes through a written questionnaire; and documentary evidence about plant operations and technical projects from company archives.

Clinical field work began with open-ended interviews of managers and technical staff at the corporate and division levels. Exploratory interviews at each plant were used to examine salient dimensions of the technological change process, and to identify new process introduction projects and principal informants.[2] Data on each project were gathered through a series of semi-structured interviews with principal informants and other project participants. Personal interviews were also used to introduce a written questionnaire which was completed by each principal informant, and to collect questionnaires and

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[2] In each case the principal informant (also referred to as the "project manager") was identified during early field work as the person who had the "most direct, day-to-day responsibility for bringing the new technology up to speed in the factory". Other project participants were identified both by plant management and by principal informants.

follow-up comments four to six weeks later. This process resulted in a 100% response rate. Interviews lasted from one to four hours, and each respondent was interviewed several times over the course of a year or more. Information was corroborated by managers at the plant and division levels. This iterative method of data gathering allowed new insights derived during the course of the research to help guide analysis and interpretation of the data collected.

Site Selection

Research was undertaken at a single leading manufacturing company, and involved eight plants located in the United States, West Germany, and Italy. The Company operates in a single, well-defined industry (precision metal components). It is the world market leader in its industry in terms of market share and reputation for product quality. Competition in the industry focuses on consistent precision quality as well as cost, and senior managers view the Company's superior manufacturing capabilities as their primary competitive tool. These capabilities are supported by extensive in-house process development activities. New machine tools and manufacturing processes are developed at the central Process Development Laboratory and in several divisional technology centers. Process equipment is also purchased from outside vendors.

The Company is organized geographically, and operations in different countries are run as separate divisions with local management. This study was carried out in three major divisions within the Company -- West Germany, Italy, and the United States -- and involved two to three plants in each division. These eight plants represent a cross-section of the Company's operating facilities. They include one large factory in each division manufacturing a core part of the product line, as well as more remote and specialized facilities. In each division, the plants studied include one operation judged by local management to be "very capable", and one judged to be less able technologically.

Limiting the research to one global, single-product corporation had several benefits, including controlling for industry and product variations. The design also facilitated access to detailed and confidential information about projects and their historical, technological, and competitive contexts [see

35,p.361;16]. Yet even within the same company, individual divisions had developed along very different lines. Therefore it was anticipated that managers in different locations might take different approaches to the introduction of new process technology [10,21,27]. Research in the context of a single company enabled identification of the effects of different managerial approaches at the local or regional level as distinguished from variations due to different corporate policies.

In summary, the Company offered an excellent opportunity to explore regional performance variations in a multi-plant network and to examine the managerial policies underlying such differences. At the same time it must be noted that the small size and restricted nature of the sample make it inappropriate to generalize from this study to more general national or regional differences in the management of technology.

Sample Selection

The sample of projects studied included all of the new process introductions identified where the technology was "new" in some way to a particular factory and which:

1) were undertaken during the preceding four years and completed or nearing completion at the time of the study;
2) represented a total capital investment of greater than $50,000 (in constant 1986 U.S. dollars); and
3) involved participants who were available for interview.

Most of the projects identified in each division met these criteria; there was no indication of selection bias across regions.

The sample included a spectrum of technological process change, from improved versions of existing equipment to introductions of novel technologies and production systems. Production technologies included metal turning and precision machining equipment, assembly and inspection systems, thermal treatment and metal forming equipment, and handling systems; the range of technologies introduced in each of the three divisions is comparable. Four to eight projects were studied in each plant. A total of 48 introduction projects

comprise the sample.

Variable Definition

Quantitative measures were developed for each of the following:

(1) Project Attributes: The size and nature of the technological change, relative to existing technology and to local operating practices;
(2) Response: The organization's response to the change, in terms of the three mechanisms identified above (preparatory search, joint search, and functional overlap);
(3) Outcome: The success of the introduction project, in terms of the startup time required and the operating benefits achieved.

Each of these variables is described below. Further details on variable definition and measurement are presented in Tyre and Hauptman [41].

Project Attributes

Because the projects varied widely in the amount and nature of the change involved, it was necessary to measure and control for these project attributes. Measurement of project scale was straightforward and was based on total investment in new equipment, tooling, and other capitalized items (stated in constant 1986 U.S. dollars). By contrast, controlling for the technological challenge involved was more complex. Six measures of technological change were identified, based on the literature of innovation and diffusion, combined with early field work. These encompass the absolute newness of the technology, the novelty of technical features relative to existing equipment in use in a given plant, the novelty of the operating principles involved for a given plant, the stage of development of the underlying technology, and the degree to which the new technology is accompanied by new product designs or new performance requirements. Data on each aspect of technological change were gathered through multiple questionnaire and interview items and later combined into aggregate scales of technological change. Reliability of scales ranged from .64 to .86 (see Appendix 1). Data reduction increased statistical reliability and interpretability in further analyses.

Aggregate scales then served as input for exploratory factor analysis to identify underlying dimensions of process change. The factor procedure employed principal analysis with orthogonal factors [20, p. 147]. Analysis revealed convergence around two factors, accounting for 53% of the variance in the aggregate scales of technological change[3].

The first factor, termed technical complexity, measures the number, novelty, and technological sophistication of new features and improved concepts introduced (such as tooling, measurement and control systems). The second factor, called systemic shift, is the degree to which the new equipment or system introduces fundamentally changed manufacturing tasks or operating principles within the plant. Projects with high scores on systemic shift represent departures from accepted manufacturing approaches, such as moving from traditional metal removal processes to net-shape forming technology, or moving from reliance on buffer stocks between operations to an integrated just-in-time flow of materials[4]. When both technical complexity and systemic shift are high, the introduction represents a "radical" shift in the technology of the factory [1,15,31].

Organizational Response Mechanisms

1. Preparatory search: The intensity of search and adjustment prior to installation of the new technology was measured by four interview and

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[3] Factor results are shown in Appendix 2. While the percent of variance explained is not large, it is considered satisfactory for exploratory work and appears consistent with findings based on clinical data [41]. Given the relatively small sample size it is important to note that results reported later in this paper proved robust to changes in factor technique or to the substitution of aggregate scales for factor results.

[4] This dichotomy can be traced back to Perrow [31]; similar distinctions have been suggested by Abernathy and Clark [1], Rogers [35], and Tushman and Anderson [40]. The measurement and implications of the distinction described here are discussed in Tyre and Hauptman [41].

questionnaire items detailing the involvement of factory personnel in proposing and developing the technical features of the new equipment or system, including early development and testing activities carried out by factory personnel. Items and scale reliabilities are shown in Appendix 3.

2. Joint Search: Measures of the intensity of joint search across organizations subsequent to installation are based on four interview and questionnaire items describing the role of personnel from outside of the factory and the importance of their contributions during the start-up process. (See Appendix 3.)

3. Functional overlap was measured by the number of lateral linkages between plant engineering and production personnel involved in the project. Eight possible linking mechanisms were identified. Since linkages are adopted cumulatively [13], a higher score represents a greater intensity of integration between functions. Primary information came from: (1) participants' sketches of the "people and project structure" on the written questionnaire and (2) participants' descriptions of the involvement and contribution of various players in the problem solving process.

Project Outcome

Multiple measures of project outcome were investigated; two principal measures, startup time and operating improvement, are discussed in this paper.

1. Startup Time: The elapsed time between the point of installation and the achievement of productive use of a new process technology is a measure of the efficiency of the introduction project, and has important economic and competitive implications for the firm [17,21,39]. Startup time influences factory efficiency and delivery performance, the ability to carry out other projects, and career growth of project participants. The following definition of startup time reflects the idea that the initial startup period, during which disruption to ongoing operations is often significant, is more costly, in terms of resources used and opportunities foregone, than the later period, when the technology is operating productively but is not yet fully debugged [9]. Startup time is the sum of:

1) **Initial startup period**: the elapsed time in months from delivery of the equipment until parts are being made in production mode; plus
2) **Introduction period**: the elapsed time in months from delivery until the project is considered complete.[5]

Information came from project schedules and key dates reported on the written questionnaire, with corroboration from project documentation and plant management.

2. Operating Improvement: Project success must be measured not just in terms of the speed of the introduction but also the effectiveness of the introduction in achieving organizational goals [25,35]. Data on improvements in operating performance came from three interview items concerning the usefulness of the technical solutions implemented, the degree to which technical objectives of the project were met, and the level of operating reliability achieved. (Cronbach's alpha test of scale reliability = .86). This approach to measuring project performance is consistent with studies of R&D projects, where judgmental assessments of operating improvement have proven reliable [e.g. 3,4].

Variables can be organized into a model depicting managerial inputs into technological process change (Figure 1).

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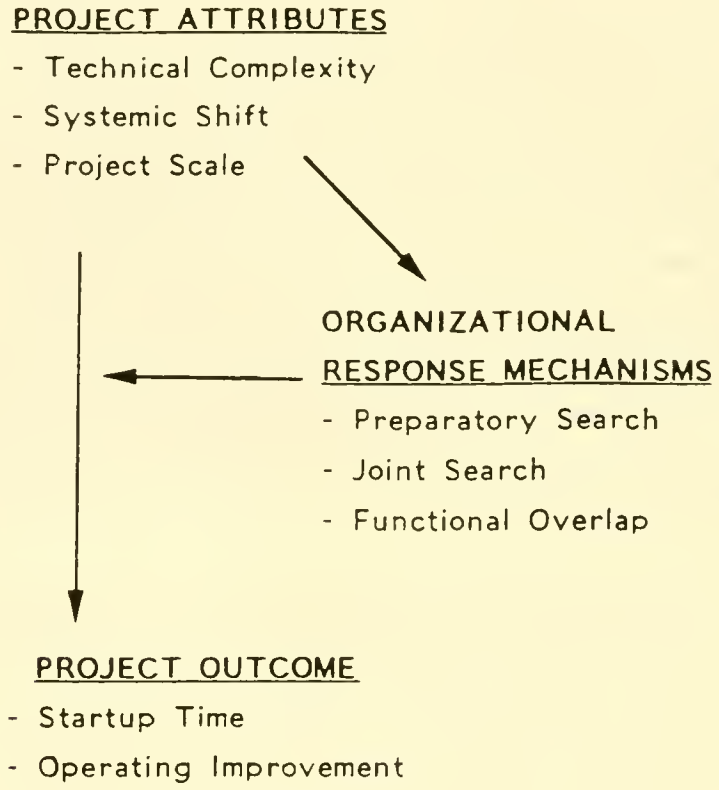
[5] This does not indicate when (or whether) the technology reaches fully satisfactory levels of performance. Performance at project completion may differ significantly from original expectations or from current requirements.

Figure 1

Key Factors in the Management of Technological Process Change



III. RESULTS

Project-Level Differences: Project Attributes, Organizational Response, and Project Outcome

The first question explored is the relationship among project attributes, organizational responses, and project outcomes for the sample as a whole. Table 1 shows the correlation matrix for the variables introduced above, and Table 2 shows regression results. Equations [I] and [II] in Table 2 examine the effect of project attributes on outcomes; they provide some initial support for the validity of the measures used here. Project attributes by themselves explain a significant amount (33%) of the variation in startup times; however they do not explain observed variations in the level of operating improvement achieved.

Considerable insight is gained by taking into account the use of organizational response mechanisms. In the regression for startup time (Table 2, equation [III]), the coefficients of preparatory search, joint search, and functional overlap are all negative and significant (at p=.05). That is, greater use of these mechanisms is associated with shorter startup times. Moreover, once the use of response mechanisms is taken into account, coefficients of both systemic shift and project scale become relatively large and significant.

Results of the full regression for operating improvement (equation [IV] in Table 2) suggest that organizational responses also play an important role in achieving superior operating performance with new technologies. Higher levels of preparatory search and joint search are both associated with higher levels of operating performance. The major difference is that the coefficient of functional overlap, while in the expected direction, is not statistically significant[6].

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[6] This result was not expected and is explored in more detail in Tyre and Hauptman [41].

Table 1

Correlation Matrix of Project Attributes, Response Mechanisms, and Outcomes

(n=48)

	TECH. COM.	SYSTEM. SHIFT	PROJECT SCALE	PREP. SEARCH	JOINT SEARCH	FUNCT. OVERLAP	STARTUP TIME
SYSTEMIC SHIFT	.00#						
PROJECT SCALE	.12	-.11					
PREP. SEARCH	-.09	.23*	.15				
JOINT SEARCH	.37**	.30**	.05	.05			
FUNCT. OVERLAP	-.05	.60**	.42**	.39**	.15		
STARTUP TIME	.52**	.35*	.07	-.39**	.04	.06	
OPERAT. IMPROVEMENT	-.21*	.10	-.01	.52**	.17	.24*	-.63**

#Orthogonal factors.
**Pearson correlation significant at $p<0.05$; *$p<.10$.

TABLE 2

Project Attributes, Response Mechanisms and Project Performance

DEPENDENT VARIABLE	INDEPENDENT VARIABLES						R^2	DF	F	P
	TECHNICAL COMPLEXITY	SYSTEMIC SHIFT	PROJECT SCALE	PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP				
I. Startup Time	.49** (.12)	.32** (.12)	.05 (.12)	- -	- -	- -	.33	45	8.7	.001
II. Operating Improvement	-.22 (.15)	.12 (.15)	.02 (.15)	- -	- -	- -	.00	45	0.9	(NS)
III. Startup Time	.54** (.09)	.74** (.13)	.32** (.11)	-.41** (.09)	-.35** (.10)	-.33** (.14)	.64	42	15.2	.001
IV. Operating Improvement	-.25* (.13)	-.27 (.18)	-.23 (.16)	.47** (.13)	.30** (.14)	.28 (.20)	.30	42	4.4	.005

Regression coefficients are standardized to facilitate comparison of effect sizes; Standard errors are shown in parentheses.
** = significant at .05 confidence level; * = .10 confidence level.

These results suggest that preparatory search, joint search, and functional overlap are important mechanisms for coping with technological process change. They appear to contribute both to the speed with which manufacturing facilities introduce new process technology, and (with the possible exception of functional overlap) to the degree of operating improvement achieved. It should also be noted that fast startups are, in general, associated with high levels of operating improvement ($r=-.63$; $p<.05$). Therefore, it is not surprising that the response mechanisms identified appear to enhance performance on both measures.

Regional Differences: U.S. versus Europe

The analysis also compared project performance of plants in the U.S., Germany, and Italy. As shown below, analysis revealed systematic differences between projects undertaken in U.S. plants and those in Germany and Italy. On the other hand, the German and Italian subsamples were statistically indistinguishable on the dimensions examined. Therefore, in the following analysis, projects undertaken in Germany and Italy are treated as a single European sample. Underlying qualitative similarities and differences within the European sample are discussed in Section IV.

The U.S. plants took longer, on average, to introduce new process technology than did European factories, and they reported lower levels of operating improvement. Table 3 shows summary statistics for the two regions. As noted, no consistent differences were discovered between divisions in Europe.

Table 3

Regional Differences in Means: Europe and the U.S.

	MEAN			MEDIAN		
	Europe	U.S.	Pearson t (2-tailed)	Europe	U.S.	chi^2
	(n=31)	(n=17)		(n=31)	(n=17)	
Startup Time	19.9	26.9	.09	17	26	.36
Operating Improvement	14.0	10.0	.07	15	8	.03
Preparatory Search	14.7	12.2	.13	13	11	.18
Joint Search	10.3	9.1	.42	9.5	8	.42
Functional Overlap	2.5	1.3	.02	2	1	.18

NOTE: Differences in means between Germany (n=17) and Italy (n=14) were also examined, however no consistent or significant patterns were revealed.

These results are examined in greater detail by means of regression analysis. In Table 4, a dummy variable indicating the region (U.S. or Europe) in which the project took place is entered into the regressions for startup time and operating improvement. The new variable is coded 1 for projects undertaken in the U.S. and controls for any "regional effect" on project outcomes not explained by other variables in the analysis.

Equations [I] and [II] in Table 4 show regional differences after controlling for measured project attributes but not controlling for variations in organizations' responses to change. On this basis, projects located in the U.S. trail their European counterparts by a significant margin. Projects undertaken in the U.S. took longer to startup than did projects in European plants by an average of 8.8 months, an increment of almost 45 percent. The "U.S. effect" on operating improvement is comparable; at the mean, operating improvement achieved with new equipment and systems introduced in the U.S. was rated 48 percent below that achieved in Europe.

TABLE 4

Regional Difference in Startup Time and Operating Improvement

DEPENDENT VARIABLE	INDEPENDENT VARIABLES							R^2	DF	F	P
	TECHNICAL COMPLEXITY	SYSTEMIC SHIFT	PROJECT SCALE	PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP	U.S. DUMMY				
I. Startup Time	.50** (.11)	30** (.11)	.16 (.12)	- -	- -	- -	.30** (.12)	.40	44	8.7	.001
II. Operating Improvement	-.23 (.14)	.13 (.14)	-.10 (.15)	- -	- -	- -	-.33** (.15)	.10	44	2.0	(NS)
III. Startup Time	.54** (.09)	.69** (.14)	.33** (.07)	-.39** (.09)	-.33** (.10)	-.28* (.14)	.11 (.10)	.64	41	13.2	.001
IV. Operating Improvement	-.25* (.13)	-.20 (.19)	-.25 (.15)	.45** (.13)	.27** (.14)	.20 (.20)	-.16 (.10)	.31	41	4.0	.005

Regression coefficients are standardized to facilitate comparison of effect sizes; Standard errors are shown in parentheses.
** = significant at .05 confidence level; * = .10 confidence level.

Europe and the U.S.: Differing Organizational Responses to Change

Data on the response mechanisms used in each introduction project make it possible to examine the source of the performance gap between European and U.S. plants in introducing new process equipment. Analysis was performed to test whether regional differences can be explained by differential use of the three response mechanisms identified, or must be attributed to other, unmeasured variables. Equations III and IV in Table 4 suggest that a significant part of the gap is explained by the way that project teams in the two regions respond to technological change, both before and after the actual installation of the new equipment. As shown, the addition of preparatory search, joint search, and functional overlap explain almost two-thirds of the regional gap in startup times (Equation III), and approximately one half of the difference in operating improvement achieved (Equation IV).

This analysis suggests that while the U.S. plants studied did tend to perform poorly on process introductions relative to their European counterparts, a large part of the gap is accounted for by the tendency of project teams in the U.S. to make less aggressive use of the three response mechanisms identified here. This argument is further supported by comparing the relationship between project attributes and organizational response variables across the two regions (Table 5). U.S.-based project teams were less likely than their European counterparts to respond to particularly challenging projects with intensified preparatory search or joint search. In fact, there is a marked tendency to undertake less preparatory search in the face of large-scale projects than in smaller introductions. Further, while the use of functional overlap in U.S.-based projects is strongly associated with the degree of systemic shift being undertaken, absolute levels of functional overlap in the U.S. are still relatively low. In Europe, six projects rated either five or six on functional overlap (out of a possible high score of 8), while no U.S. project rated higher than four. Conversely, five projects in the U.S. had an overlap rating of 0 (the lowest possible score), as opposed to one such project in Europe.

IV. ANALYSIS OF REGIONAL DIFFERENCES

Regional differences in startup time and operating improvement cannot easily be attributed to differences in the products produced (which are closely comparable across regions) or in the difficulty of projects undertaken; as shown in Table 4, significant unexplained differences persist even after controlling for the size and nature of the change. Rather, results suggest that there exist systematic differences across regions in teams' use of the response mechanisms examined here. This finding raises important questions about the source of regional differences in search activities and, in turn, in the ability of the plants studied to introduce new manufacturing technologies.

To answer these questions the following analyzes the historical evolution of the manufacturing organization and its process technology in each division. As discussed below, local managerial choices dictated that regional operations evolved along different lines, acquiring different capabilities and operating assumptions[7] (see Figure 2). Further, these attitudes and capabilities, once created, proved to be long-lived and resistant to change. Starting in 1985 (the year before initiation of this study), management at the corporate and division levels began taking vigorous action to address what they viewed as historical weaknesses in the U.S. operations. However the evidence suggests that embedded organizational practices and constraints continued to affect efforts to introduce new process technology well after this date.

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[7] As background, it is important to note that these differences developed within particular social, political, and economic contexts at national and regional levels. However the discussion in this paper is limited to specific intrafirm comparisons; it does not explicitly examine the impact of larger national or cultural variables.

Figure 2

Summary of Organizational Differences Across Regions

Europe	U.S.
1. TECHNOLOGY STRATEGY	
* Coherent strategy for investment in new process technology;	* No long-term planning for equipment and process investments.
* Considerable experience in introducing advanced process technology;	* Relatively low levels of investment in new process technology;
* Strong installed base of advanced technology;	* No local equipment development activities.
* In-house equipment development at local levels.	
2. ORGANIZATIONAL PRACTICES	
* Systematic tracking of ongoing operating improvements;	* Little attention to ongoing efficiency improvements:
* Ongoing development in conjunction with external and internal suppliers.	* Purchase solutions from equipment and tooling suppliers.
3. ENGINEERING INFRASTRUCTURE	
* Integration of plant-level engineering and production roles (Italy);	* Formal distinctions between engineering and production personnel echoed in informal working patterns.
* Extensive in-house training and rotation among functions and facilities (Italy);	* Significant turnover among plant-level engineers;
* Formal distinctions between engineering and production combined with close informal working relationships (Germany);	* Uneven levels of technical competence among engineering and production groups.
* Considerable formal training for engineering and production personnel (Germany);	
* Strong internal capabilities for real-time process and equipment modification.	

Table 5

Organizational Responses to Technological Change

[1] Projects Undertaken in **EUROPEAN PLANTS** (n=31)

	Organizational Response		
	PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP
Project Attributes			
TECHNICAL COMPLEXITY	-.08	.51**	.01
SYSTEMIC SHIFT	.27*	.29*	.39**
PROJECT SCALE	.05	.03	.26*

[2] Projects Undertaken in **U.S. PLANTS** (n=17)

	Organizational Response		
	PREPARATORY SEARCH	JOINT SEARCH	FUNCTIONAL OVERLAP
Project Attributes			
TECHNICAL COMPLEXITY	-.25	-.11	.31
SYSTEMIC SHIFT	-.15	.27	.62**
PROJECT SCALE	-.56**	.04	.04

Spearman correlations: * = significant at $P < .10$; ** = $P < .05$

Technological Strategy and Decision Making

1. European Operations: Local managers in the Company's European divisions have a high degree of autonomy over operating decisions. However, strategic decisions relating to manufacturing operations and technology are made by centralized management committees composed of senior managers from division and central staffs. Product line rationalization, as well as process and product development, have been aggressively pursued and centrally coordinated through this vehicle in all European operations since the mid 1960's.

As a result, a coherent strategy has guided process development in the European divisions for almost 20 years. In the early 1970's, the Company's central Process Development Laboratory[8] introduced the first generation of proprietary "ABC" machine tools, which incorporated new concepts for precision metal finishing. German and Italian plants soon adopted the technology, completing hundreds of introduction projects. Describing the process, one senior manufacturing manager observed, "It took a long time to debug those early machines and we had many problems. But we learned a huge amount about the equipment, and about how to bring new technology into the plants."

In the late 1970's, the Development Lab introduced the second generation of "ABC" machine tools. The new equipment was based on existing machining concepts but incorporated a proprietary microprocessor control system. This development enabled European plants to introduce one standardized control technology from the start. As a plant manager explained, "We made sure that not one machine was introduced that did not have the possibility to communicate with other machines on the floor."

In the early 1980's, the Company's development thrust turned to linking separate machines on the shop floor. The result was the introduction in German and Italian plants of a centrally-controlled, fully integrated machining and assembly system capable of 24-hour operation with minimum staffing. Finally, in

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[8] The Process Development Lab is located in a different European country. It is remote in location and language from any of the divisions studied.

the late 1980's the objective was to develop more flexible integrated systems, where appropriate, for greater market responsiveness in low-volume product types.

2. United States Operations: Recent history in the Company's U.S. division differs sharply from that in Europe. Until the mid-1980's the U.S. division enjoyed full autonomy over local policies and operations, maintaining an arm's length relationship with the parent Company and its centralized management committees. Over time, these local policies created a very different environment for technological change. Operations during the 1970's and early 1980's were characterized by fragmented product offerings and low quality levels relative to the Company's standards in its other divisions. During this period, as one division manager described it, "The U.S. division had been making money, but in a short-term mode. They were not investing in technology or productivity."

Until 1985, the U.S. division treated its plants as decentralized, independent profit centers. There was very little product line rationalization or coordination of process development. According to the engineering manager at one U.S. plant, "Until recently, there was no real long-term planning on the subject of manufacturing processes and equipment. Every capital request was reviewed in isolation."

While a number of early examples of internally-developed "ABC" machine tools were introduced in the early 1970's, process investment slowed in later years. When factories did buy new capital equipment there was no explicit effort to build on existing capabilities and concepts. Decision makers eschewed the second-generation, microprocessor-based "ABC" machines, relying instead on external equipment vendors and traditional manual technology. A few projects were undertaken to integrate separate machining operations, but plants ended up with multiple, incompatible machine control systems. Whereas the German and Italian divisions maintained active equipment development efforts to complement work at the central Development Lab, the U.S. equipment development center had been closed in 1972. With that action many of the functions of the division-level technology group had been discontinued, and manufacturing engineering depth was seriously eroded.

Organizational Practices and Assumptions

Partly as a result of this pattern of decisions, both the German and Italian divisions featured strong installed bases of process technology, strong manufacturing capabilities, and technically capable personnel, each of which largely was absent in the Company's United States division. Productivity growth in Europe had averaged 7% per year between 1970 and 1985, whereas the comparable figure in the U.S. was 1.5%. Similarly, while local variations prevent exact comparisons, U.S. plants were judged by Company management to be considerably behind their European counterparts in terms of defect and quality levels, and in measures of operating efficiency such as cycle time and machine set-up time.

Following a renewed focus by Company management on improving U.S. operations starting in 1985, differences between regions in specific manufacturing performance indicators began to narrow. However, patterns and assumptions developed during the earlier period continued to influence strongly the way new process technology was introduced into plants. Most important among these factors was a relatively weak organizational infrastructure for ongoing process development and refinement. In the U.S., process improvement activities were not monitored consistently before 1986. As one senior manager in the region explained, "There were other ways to show a profit besides worrying about operating efficiencies." According to a manufacturing engineer who had worked in both the European and U.S. plants:

> In America, it's easy to get plant engineers to start working on large projects, with formal project management structures, but it's extremely difficult to keep attention focused on the details over time. People tend to drift away to other problems when the work is only half done, leaving all the little tasks that actually mean the difference between success and failure in a new system.

In both Italy and Germany, plant-level engineers spent a great deal of time developing and achieving annual improvement plans. These plans were formally specified in terms of targets for productivity, quality, and other measures of operating effectiveness, and monitored at the division and corporate levels. While improvement activities were managed differently in the two European divisions, plant-level personnel in both countries generally had several process improvement projects underway at any time. These "miniprojects" frequently involved iterative

development and testing of new tooling or devices in conjunction with the division's local technical center or with outside suppliers. According to one senior technical manager:

> When we say that European plants are specialized by product line, we mean that they concentrate not just on making those parts but are also responsible for both product and process development. Each division is a development center for a specific technology. Underlying this is a strong requirement -- and will -- to improve on what now exists.

This suggests an important difference between the two regions in the way in which project teams used external sources of expertise, both inside the company and outside it, to explore technical problems and potential solutions. With a few exceptions, U.S. project teams generally expected to purchase solutions from equipment vendors or component suppliers, whereas project teams in Europe were more apt to use outsiders as a resource for ongoing development of a given item. This contrast is apparent in the way project teams in the different regions viewed the development of new tooling to support new process technology. In Europe, tooling development typically was viewed as a critical task requiring the combined knowledge of both plant-level engineers and tooling experts from internal and external suppliers. For instance, one project leader in an Italian plant explained:

> We identified very early what would be the most critical problem to solve: developing tooling of sufficient precision to allow us to take advantage of the new computer-controlled technology. And we devoted a great deal of effort to a thorough tooling study. An important part of this process was working with the tooling experts at the equipment developer to understand how to utilize this new technology.

Developing the tooling systems which were not just usable but optimal was considered one of the factory's regular responsibilities and was a focus of attention before, during, and after the introduction itself. In several instances, this emphasis blurred the exact boundaries of the introduction "project" itself. As one German project leader stated, "You really can't call all the continued effort at tool optimization part of the project -- that's something we are always doing, on all our equipment."

In contrast, many U.S. project managers expressed the view that the most efficient approach was simply to purchase a satisfactory tooling package from the equipment vendor, thereby avoiding the need to invest time in tooling development. One manager attributed the problems that plagued a particular introduction to the fact that the machine had not been purchased along with a full complement of tooling from the vendor, rather than to examine internal tooling development practices. Similarly, as long as tooling worked, there was little effort devoted to optimization. Another project manager explained that the external supplier had delivered a tool set "which worked right off the bat. It never presented a problem, so we never had to run any more trials or ask for changes."

The notion that technology can be purchased "off the shelf" extended to new manufacturing equipment from the Company's Process Development Lab. As a senior U.S. manufacturing engineer explained;

> The new machines from Central Lab require a shift in skills and operating procedures -- but that is all provided. You don't need to have all the knowledge in place because the machines come complete with hardware and software, reference manuals, and service engineers from Central to do the training and initial set-up. Once you learn how to push the buttons, these machines are quite simple to use.

This expectation, however, was not borne out in practice. In almost every instance where equipment from the central Lab was introduced into a U.S. plant, project participants complained that the machine did not in fact operate according to specifications, and that the service engineers who performed the initial set up did not complete the task of debugging the equipment or training local operators. Engineers from the Process Development Lab, in turn, argued that U.S. managers and technical personnel expected Lab engineers to run their equipment for them. While there were notable instances in which U.S. project participants invested heavily in joint search with equipment vendors, all but one such case involved vendors external to the company and technical features which were relatively well-developed, with low to medium levels of technical complexity.

While European project participants also complained about the lack of technical support from the central lab, they simultaneously stressed that part of

the development responsibility rested with the factory. As a divisional manager explained:

> Engineers in the labs are experts in the machine technology, but we are the ones who really understand the manufacturing process. Therefore, to take a machine which meets the basic specs and make it respond to all our requirements --that's the job of the factory.

Engineering Infrastructure

The different attitudes and capabilities displayed in Europe and the United States appeared to be rooted in different engineering "infrastructures": that is, contrasting approaches to the organization and development of technical talent in the manufacturing environment. Although Germany and Italy differed in many aspects of their engineering infrastructures, both divisions shared common themes which were absent in the U.S.

1. Italy: In Italy, respondents sometimes had trouble distinguishing engineering and production as separate functions. In several cases, an individual was described as having direct responsibility for manufacturing, but also maintaining a seat in the plant technical office. According to the division's director of manufacturing technology:

> The word "engineer" is hard for us to define. There are at least two possibilities this can refer to within the plant. First and foremost, the backbone of this organization is the "shop floor engineer". He is on the line: generally a foreman or assistant foreman. He is responsible for production and quality, as well as for cost and quality improvements. He also has hands-on responsibility for new projects. Second, there are factory technical offices. These are the future-oriented engineers; they support production people in ongoing operations but they also develop new kinds of solutions. But they never have direct project responsibility for new process introductions. It's important that production people have responsibility for new technology from the start.

Personnel development in the Italian division included considerable job rotation between direct manufacturing supervision and the plant technical office. All levels of manufacturing management and technical experts go through a "spiral of rotation" which begins with machine attendance and generally includes

experience in a variety of manufacturing and project situations. Promising individuals also move between the division technical center and the factories. While the Italian technical center itself is very small, its staff works closely with plants to understand their needs, and with outside machine shops or component suppliers to design and implement new ideas for machines or devices for use in the plants. In addition, people move between plants over the course of their career, creating a basis for sharing knowledge and experience among plants in the division. The Italian division was noted for its ability to utilize and build on existing knowledge through extensive in-house training, team assignments, and cross-fertilization among areas and plants.

Many observers within the Company pointed to the deep capabilities developed by this system at the level of production setters, supervisors, mechanics and maintenance people. As the Company's director of manufacturing described it:

> Our Italian plants put less emphasis on the pure engineering excellence of their people than do, say, the Germans; but their strength is in the very careful, conscious management of their technology. They have created a very high level of interest and ability among **all** their people.

The outcome, as one U.S. engineering manager remarked, was that:

> The Italians are wonderful at making all kinds of process refinements -- and it's because of the management there, not the product line or anything else. They love to "fiddle" with their equipment. But it's not a game -- they are very conscientious about applying their knowledge to their operations. You take a machine which we consider great, but they make lots of little innovations and end up running twice as much product on it.

2. Germany: In the German division, the plant-level engineer is conceived quite differently. Engineering is organizationally distinct from production management and generally reports directly to the plant management. Many plant-level engineers have formal engineering degrees, as distinct from the apprenticeship

undertaken by operating personnel. Indeed, there are important distinctions within the engineering office based on individuals' formal technical training.

Formal responsibilities in the plant are clearly bifurcated. Engineers are directly responsible for cost and quality improvements. The chief engineer is the formal project leader for planning and administration of new process introductions, and implementation is generally the direct responsibility of a process engineer in his or her group. Production managers, meanwhile, are responsible for meeting output targets in terms of quality and quantity. They are also expected to support the engineers' improvement efforts, principally by allocating people and development time to improvement and introduction projects.

However, these clear distinctions often break down -- or are actively broken down -- in actual operating procedures. Two of the three plants studied in Germany presented exceptions to the standard organization structure. One plant was composed of several small shops or subfactories; within them, engineers reported to manufacturing shop managers. In fact, in at least one of these shops, the production manager was also the chief engineer. In another plant, in addition to the "real" engineers with degrees working in the technical office, there were also engineers who "sat on the production floor" in each department and reported to manufacturing managers.

Further, there was considerable technical expertise among production personnel at all levels. Production managers typically were shown considerable respect by the degreed engineers on the basis of their technical know-how. As one degreed engineer explained, "The manufacturing supervisor and the department manager are really engineers too -- they are the floor engineers." While their technical capabilities varied, manufacturing managers at this level all received some formal technical training, and they were the first ones to respond to technical problems on the line. Indeed production department managers frequently came from the plant's engineering office. In many cases, junior engineers in charge of the introduction projects reported in an informal matrix arrangement to the production department manager.

Relative to Italy, technical personnel in Germany were less likely to rotate among plants or between plants and the division technical office. On the other hand, considerable efforts were made to link technical development activities at

various facilities. First, five of the seven plants in the division (including two of the three plants studied here) were located in a geographically centralized "complex" along with the division headquarters and technical center. The division technical staff, which was several times the size of the group in Italy, was responsible for designing, building, and helping plants to implement new equipment and systems. Especially in plants located in the central complex, there was considerable interplay between plant engineers and engineers at the technical center. Further, factory personnel with particular areas of expertise or experience were often consulted or even borrowed for projects undertaken in other plants in the complex.

While Italy was known within the Company for its penchant for "fiddling" with production equipment once it was on the floor, Germany was known for doing a great deal of technical preparation of both the new equipment and the existing factory before attempting a new introduction. This was consistently recognized by those interwiewed as being of utmost importance. One project leader explained:

> This was one of our most successful introductions because we worked explicitly to identify all the most important unknowns, and to develop solutions, **before** the equipment was shipped or, in many items, even before it was ordered. If you really think about it, you can identify and address 95 percent of the hard issues beforehand.

3. United States: The formal organization structures of U.S. factories resembled the German pattern, with separate engineering departments reporting to the plant manager. However, with the exception of one small subcomponent plant studied, informal integration of technical priorities and production requirements was often more difficult to attain. In several instances, plant-level engineers blamed delays in introducing new equipment on the difficulty of getting the production manager to set aside time for operator and supervisor training or for on-line testing of tooling or devices. Manufacturing managers, meanwhile, frequently attributed disruption and startup delays to the absence of engineering support during startup and later debugging of the new equipment.

Further, many individuals in the company argued that engineering capabilities in U.S. plants were too thin. In the U.S., formal and in-house

technical training or personnel development through job rotation received much less attention than was true in Europe. Plant-level engineering capabilities, and the relationship between engineers and production people in the plants, varied widely. Unlike the situation in European divisions, high turnover among engineers was a frequently-cited problem. As one senior manager said with dismay, "Many of the engineers in these plants are not even from our industry. They do not <u>really</u> understand the products and processes involved."

In addition, key production personnel frequently lacked necessary technical skills. According to one European engineer who had worked in various U.S. operations:

> The production supervisor is the place where there is very often a big gap. In too many cases, the supervisor does not have sufficient understanding of modern production technologies, so he ends up relying on operating people for process expertise. Sometimes the operators have long experience and special aptitudes, but sometimes that is not the case. So it can be hard to carry out big projects successfully.

Another engineer explained the danger in this situation:

> Expertise at the operator level should not be what is critical. Productivity of both old and new machines comes from the engineering backup in the plants -- the engineers, maintenance people, and supervisors. That small group has got to be the organizational intelligence between management and operators. They have to be able to teach operating people, to guide them to focus on key problems, not just rely on operators' expertise. The competence of that group and how it is cultivated is the key to the ability to bring in new machine technology.

V. CONCLUSIONS

This paper has analyzed the success of new process introductions undertaken by a single technology-based company operating in both Europe and the United States. Analysis suggested that observed regional differences in performance can be traced, in the short run, to underlying differences in the way project teams respond to technological change. The response mechanisms identified -- preparatory search, joint search, and functional overlap -- were shown to support improved project performance in terms of startup time and

operating improvement. Project teams in Europe and the U.S. differed in their propensity to use these mechanisms in dealing with challenging introductions, which contributed to different levels of success with new process technology.

More importantly, differences at the project level have been examined in their organizational and historical contexts. Based on this evidence, the paper has argued that the response patterns observed are rooted in historical differences in the management of technology and technical resources at the local operating level. This study identified three related areas of managerial choice that affected the ability of individual plants to respond aggressively to the challenge of technological change. The first area relates to the style of managerial decision making for investments in process technology. In Europe local operating managers developed coherent strategies to guide process development efforts over time and across facilities. To implement their strategies, divisions invested aggressively in capital equipment and development activities. The second area of concern relates to practices and relationships that govern existing manufacturing processes. In European plants a consistent, top-to-bottom emphasis on continuous process improvement showed up clearly in high levels of productivity improvement and quality performance, and in the attitudes and assumptions that project participants brought to new process introductions. This determination was supported by a tradition of cross-boundary problem solving between the manufacturing organization and outside suppliers of technology. Finally, the third area of managerial choice which differed across regions was the system for building technical competence in the manufacturing organization. In the Italian plants in particular, continuous managerial emphasis on personnel development, cross-training, and cross-fertilization appears to have created a strong technical skill base and dense linkages across functions.

These results have important implications for understanding and managing technological process change. First, the research reported here adds substance to the notion that the introduction of new process technology requires considerable ongoing adaptation and even innovation at the plant level [1,25,34,42]. It further suggests that specific mechanisms to support adaptation can be identified, classified according to innovation stage and organizational locus, and measured. The constructs of preparatory search, joint search, and functional overlap introduced in this paper are potentially powerful tools for

managing technological process change and for understanding its organizational implications.

Further, this research explicitly links the ability to utilize new process technologies to existing organizational practices and past investments in technical capabilities [2,15,36]. While a good deal of literature has focused on managing technological projects and project teams [4,19,21,22], this research suggests that project activities will themselves be constrained by embedded organizational features. Specifically, the research suggests that responses to new process technology will be affected by the pattern of past investments in new processes and equipment, by familiar operating routines and procedures, by established working relationships across functional and organizational boundaries, and by practices for developing technological capabilities at the plant level. Indeed these features of the organization emerge as critical strategic assets or liabilities in dealing with technological process change at the plant level.

At the same time the evidence presented in this paper suggests that the introduction of new process technology can, in turn, alter embedded organizational practices and technical competencies. The effect is likely to be cumulative, spanning many years and generations of new technology. As described in the last section, critical differences among the operations studied in this paper evolved over a period of ten to twenty years. Examined in this time frame, decisions regarding investments in new process technology and the management of subsequent improvements can be seen to transform the organization and its capacity for technological change.

In short, this paper argues that there are strong relationships in both the short and long term between the introduction of new process technology and its organizational context. More research is needed to describe these relationships and their managerial implications. While the findings reported here are suggestive, it must be remembered that this study was confined to a single company. Further, no attempt has been made explicitly to link managerial choices in different operating units to underlying political and cultural factors in the local environment. Further empirical work is needed to better understand the cultural, institutional, and political forces that influence or constrain the management of technological change in different regional contexts [26,33,43].

More research is merited to explore the relationship between the introduction of new process technology and its organizational setting within the global corporation. The questions involved are important for developing new insights into the problems of technological change within organizations. Further, these issues are of vital practical concern in light of the serious questions surrounding the global competitiveness of the U.S. manufacturing sector.

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Appendix 1

Aggregate Scales of Technological Change

SCALE NAME	DEFINITION	NUMBER OF VARIABLES	CRONBACH ALPHA
Technology Newness	Newness of technical features relative to technology previously available	4	.86
New To Plant	Familiarity of technical features relative to equipment existing in the plant at the time of the introduction	4	.83
New Base	The degree to which the new technology is based on technical or operating principles new to the plant or the company	4	.77
Ongoing Development	The degree to which the new technology is a prototype installation	3	.65
New Product	The degree of change in product specifications introduced with the new equipment	3	.64
Required Performance	The stringency of performance requirements (cost and quality) relative to existing standards	4	.65

Appendix 2

Contribution of Scales to
Technical Complexity and Systemic Shift Factors

	Contribution to Factor 1: **Technical Complexity**	Contribution to Factor 2: **Systemic Shift**	
Aggregate Scale:			
1. New Technology	**.84**	.12	
2. New to Plant	**.54**	**.57**	
3. New Base	.07	**.99**	
4. Ongoing Development	**.52**	.31	
5. New Product	.34	.17	
6. Performance	**.44**	.02	
	---	---	
Variance Explained by Factor:	.27	.26	total=.53

Note: Factor analysis used principal analysis and varimax rotation. Oblique rotations were also tried but did not improve results significantly. Similarly, inclusion of a third factor does not improve explanatory power.

Appendix 3

Derivation of Organizational Response Variables

1. Preparatory Search

What role did technical support and production personnel play in the following activities before the equipment arrived at the factory?

1. Propose purchase of the new equipment.
2. Developing new technological concepts.

(1-5 scale: 1 = not involved; 2 = were informed; 3 = gave advice; 4 = major support; 5 = fully responsible.)

3. Describe any studies undertaken by plant personnel prior to delivery of the new equipment. (Interview item, with questionnaire commentary.)

(1 = no studies; 3 = some study, but not unusual amount; engineering personnel performed some analyses; 5 = intensive study; we made a major tool life project, and several people were assigned; we made a large effort to resolve problems in the systems choice before we even ordered the equipment...)

4. Describe the process of pretesting the equipment at the vendor (or, where applicable, in the plant) prior to delivery (or to startup). (Interview item, with questionnaire commentary.)

(1 = We had a runoff test, but it was perfunctory; the vendor had everything set up just right, and we were not allowed to change the conditions; the people we sent to the qualifying test did not know what to look for; 5 = We did extensive runoff testing at the vendor's, and we refused to accept the equipment until it worked to our standards; once we received the equipment, we set it up off-line and did extensive testing or routines and tooling.)

Scale alpha = .67

2. Joint Search

1. How helpful were people from the following groups during this introduction?
   a. Equipment vendor or in-house development center?
   b. Personnel from sister plants?
   c. Outside advisors?
   d. Technical experts from division technical center?

(1-5 scale: Made critical contributions ___ no real contribution.)

2. Where did people get the know-how to accomplish the introduction of the new equipment -- how true are the following statements?

a. Outside experts provided guidance.
b. Training by the vendor provided essential know-how.
(1-5 scale: True for this introduction _____ Not at all true.)

3. Describe the role of outside experts in the startup process.
(Interview item, with questionnaire commentary)

(1 = Not a partner in the problem solving process; sold the equipment and the normal services (such as initial installation help, replacement parts but was not really part of the project team; 5 = Part of the problem solving team; the vendor gave us lots of important ideas, we discussed many of our problems with him; I learned a lot about this technology by working with the supplier; the expert from the head office came to this plant and worked closely with me and my colleagues, he was an important partner in the introduction project.)

Scale alpha = .79

3. Functional Overlap

Primary information came from:

1. Participants' sketches of the "people and project structure" and their commentary of the sketch;

2. Participants' descriptions of the problem solving process: who was involved and the modes of communication and contribution;

Information was coded for mechanisms listed below:

Mechanisms for Mutual Adjustment and Feedback (1)

- Individuals from different functions work together directly to identify and solve problems in the new process.

- A manager who is not directly involved with the introduction plays a linking role between functions.

- A project manager(2) has ongoing responsibility for both technical and production activities in the plant or department.

- The introduction is organized as a special interfunctional task team.

- The introduction is one of many activities performed by a multi-level, multi-functional task team.

- One or more individuals act as liaisons between functions (e.g. an engineer participates directly on the production line; a production operator participates in an engineering study).

- Permanent or temporary transfer of personnel across functional areas links

the production area with the locus of technological decision-making.(3)

- The introduction takes place within a semi-autonomous, multi-functional unit within the plant.

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(1) Descriptions adapted from Galbraith [13].
(2) Formal or informal designation; multiple managers possible.
(3) Only transfers directly related to the introduction are considered. Previous transfers undertaken as a general policy are not included.

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